Computer Networks & Software, Inc.

ACAST Aviation Certification
and
Business Case Project

Draft
Certification Roadmap Report

to

NASA GRC

Prepared by *Aviation Management Associates Inc.*

NASA Contract No. NASA-CNS NNC04QA32D

February 28, 2005

7405 Alban Station Ct., Suite B-215, Springfield, VA 22150-2318

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1.0 Introduction

The purpose of this report is to establish the approach and concepts to be used in defining the business case for the National Aeronautics and Space Administration's (NASA) project to develop multi-mode, multi-function digital avionics (MMDA) for use in the Next Generation Air Transportation System (NGATS) and for global aviation applications. This research is under the umbrella Advanced CNS Architectures and System Technologies (ACAST) Project.

The overall ACAST goal is to develop and design the transitional architecture and enabling system technologies to transform the NAS through a high-performance integrated Communications, Navigation and Surveillance (CNS) system. Other specific elements of the ACAST Project include the definition of a global air/ground network architecture, the development and identification of efficient aviation spectrum utilization, the implementation of efficient oceanic/remote operations through improved communications and surveillance, and increased air-ground data link performance and capacity for terminal, en-route and surface operations.

An essential element that is complementary to the advanced technology development research is early integration of business and economic factors so that the research can be transitioned to industry for commercialization. The business case development will assess the policies, strategies and action plans related to operational concepts and transition strategies. These non-engineering areas are not separate tasks, but an integration of activities that deliver valid, supportable concepts that the user community can embrace and understand well enough that they will actually support the technology, make investments and transition to new avionics equipage.

Successful commercial deployment of avionics products depends upon understanding the concept, context, integration and value of their use. Who will purchase; what problem does it solve; what is the purchaser willing to pay; what benefit does it create; what functionalities or capabilities are needed, wanted or desired; what does it cost; what is its value? Unless the business case is understood, investments in technology that produce no commercial benefit are limited to scientific research. Given the expenditures by NASA to improve the safety, capacity and efficiency of aviation infrastructure, it is important to understand and appreciate the wisdom of investments and their impact upon how they can and will improve the National Airspace System. This task provides operational concepts; business case development/analysis and transition strategies for NASA identified technologies.

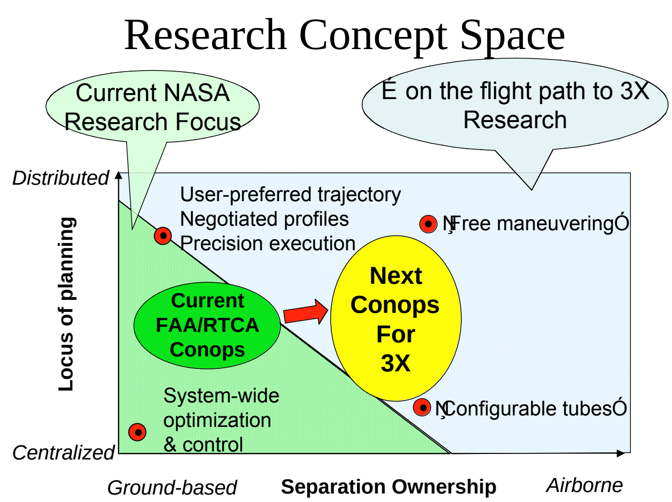
This Business Case Development Report for MMDA Certification includes the approach; information needs to support the business case, concept development, and benefits definition. A business case model has been developed to capture information for the business case during the research. This model has also been tailored to meet the Office of

Management and Budget's Circular A-11 processes, specifically Exhibit 300, that is used to justify federal investment and reduce risk to the private sector.

The business case proposes two parallel development paths – one supporting improvements in communications for air carrier aircraft, the other to help general aviation transform to the NGATS that emphasizes 4-D trajectory-based separation and network-enabled operations. In order to collect information supporting the business case, the business case needs a concept of operations. This concept must be driven by perceived needs in the market place that can then be refined using the Voice of the Customer[1].

2.0 Concept of Operations

The NGATS is being driven by the recognized need that traffic in the NAS could grow close to three times the traffic by 2025 (3X). Significant changes in the current concepts of operations will be needed to accommodate this demand while maintaining safety and security[2]. The changes needed to transform the NAS and reach global interoperability are centered on 1) a shift toward more autonomous aircraft operations, 2) a significant improvement in situational awareness by all participants, and 3) the need for significantly greater information exchange between the aircraft and the ground.



The concept space must shift to fundamentally transform air transportation and the services provided by the air navigation service provider (ANSP). For the NAS, the ANSP is the FAA and some terminal and airport services are provided by the Department of Defense. Under the current concept of operations, separation is ground based and is the responsibility of the ANSP in instrument flight conditions. In visual conditions and operating under visual rules, the pilot is responsible for separation. The desire is to move closer to visual capacities in instrument flight conditions. NASA's current research is focused on optimizing the current system against the current concept of operations, where

[1] "Voice of the Customer" is a major tenant in Design for Six Sigma. It is a disciplined approach to defining what the customer needs and wants and translating into functional and measurable requirements.

[2] Readers can see the full Next-Generation Air Transportation System report at www.jpdo.aero

the air traffic controller has significant workload to separate, sequence, and space traffic. The general research shift is to move from the current concept of operations to a new concept that can support safe transformation to 3X traffic.

This ***flight path to 3X*** is conditioned on two central themes that the MMDA research is well positioned to support:

- 4-D trajectory-based separation, sequencing and spacing
- Network-enabled operations to provide common situational awareness and the right information at the right time to make the right decisions – whatever the individual's role in air transportation.

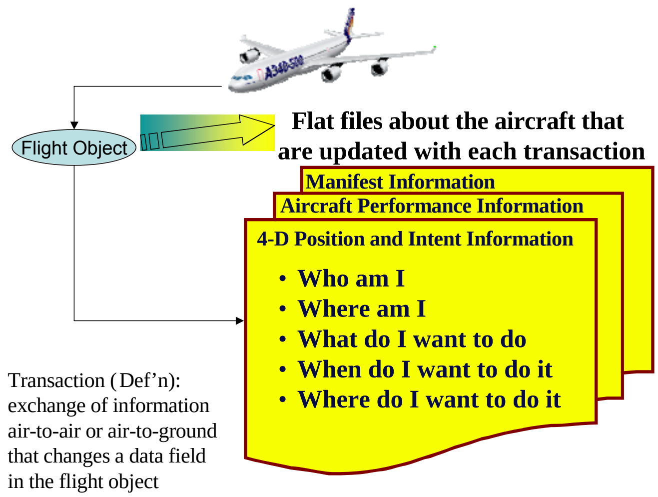
There are specific enabling research challenges on the ***flight path to 3X*** that help shape the research concepts supporting transformation to the NGATS:

- Changing the role of the controller from active control of separation, sequencing, and spacing to management by exception – allowing automation to separate, sequence, and space aircraft, first in the en route environment and then in the terminal environment.
- Removing aircraft uncertainty through use of intent (between the aircraft and the ground and between aircraft).
- Enabling autonomous aircraft operations in low-density airspace so that aircraft can separate, sequence and space themselves when traffic density allows.
- Allowing aircraft to fly their designed optimum profiles during departures, en route and arrival. This means accommodating a significantly different fleet mix of aircraft by 2020 with considerable operational autonomy.
- Eliminating airspace distinctions between en route and terminal airspace.
- Provide the automation, networking, and communications capable of supporting consolidated airspace management – fewer controllers and fewer facilities to manage the airspace and air traffic.
- Investing in highly reliable, secure automation and networking research that can provide fail soft, retaining sufficient capabilities to assure separation in a failed mode.
- Adding existing airport capacity by maintaining throughput as ceiling and visibility degrade.
- Help communities make local decisions to add runways at existing airports and promote new airports where community growth is expected to outstrip existing air transportation infrastructure.

In defining an interim concept of operations consistent with the NGATS for the MMDA business case, the 4-D trajectory and network-enabled operations are selected. This creates two paths for MMDA. One for air carrier aircraft is dedicated to communications to send and receive information making the aircraft a ***node-on-the-net*** for network-enabled operations. The other is for general aviation, where additional integration and disruptive technology is needed to emulate the capabilities of air carriers to support 4-D trajectories and intent.

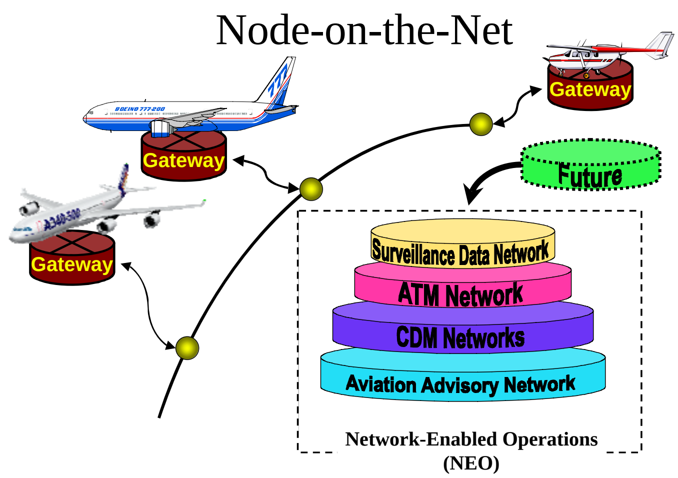
4.0 Concept of Operations – Air Carrier

The basic need for air carriers is to be connected to network-enabled operations and be able to generate 4-D trajectory and intent information. The information required for 4-D trajectories and intent is resident on the aircraft already. A new information control unit may be needed to extract this information, format the data and prepare packets for transmission to the ground. In addition, there will be a need to receive information, reformat to the aircraft systems, and send the packets of information on to the aircraft elements that need the information. The output from the aircraft is called the flight object and the networks of the network-enabled operations use the flight object for common situational awareness. It contains structured information defined by the concept of operations. The flight object is the repository for transactions that change data. For example, security operations within the NAS may need the passenger manifest. The manifest remains unchanged during the flight, but is available on the network. Aircraft position changes continuously, and the shipment of the flight object file for position and intent needs to be sent to the network on a much more frequent basis, with each update of position and/or change in intent.

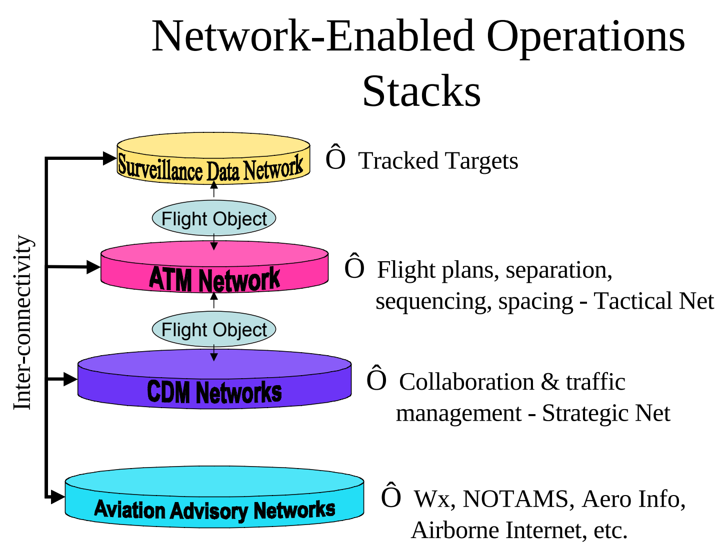


There is a need to connect the aircraft to the network and the aircraft becomes a node on that network. ***Node-on-the-net*** has been used to describe this new connectivity. The concept is simple to understand and embrace by the user community and matches NASA Glenn's strength and skills in communications. NASA Glenn can take the leadership role to characterize this new air-to-ground connectivity and mobile air-to-air capabilities. ***Node-on-the-net*** does not limit connectivity to a single network, but allows the aircraft to connect to multiple networks, both of the ANSP and commercial services.

The ***Node-on-the-net*** is first a demonstration of capabilities, then national and international standards are put in place and the ***Node-on-the-net*** becomes the basis for a global air transportation network concept replacing the current Aeronautical Telecommunications Network. The ***Node-on-the-net*** will need a gateway to manage information flows. This gateway can support security, connection, and quality of service. Note that the gateway can be either on the aircraft or on the ground, depending on results of architecture trade studies.



The network-enabled operations represent the transformation of communications, focusing on information sharing, improved decision-making, and common situational awareness. Multiple networks to provide services will use information like the flight object and other aircraft related information. The aircraft can access information from a wide variety of sources through networks, conditioned on authentication and authority to access the information. There is an opportunity to invent this new global network from the aircraft to the ground where the aircraft then connects to network-enabled operations.



The Surveillance Data Network is undergoing definition by the FAA through a contract with Boeing. The Air Traffic Management (ATM) network is to be demonstrated late this year, also by Boeing and several teammates. The CDM networks (collaborative decision making) exist in two separate entities, the FAA's Traffic Flow Management System (undergoing upgrade) and the airline components of traffic flow management. Networked aviation advisory services are not yet integrated. Development of the network-enabled concepts will continue well through 2009 and it is important for NASA Glenn to be the advocate and leader for ***Node-on-the-net***.

2.1 Node-on-the-Net Characteristics

The ***Node-on-the-net*** will have certain desired characteristics already identified within a proposed Global Aeronautical Network as follows:

(Capable of producing value-added benefits,
(Capable of operating globally,
(The network is link independent, making the communications mode transparent to the users,
(The system will need to be interoperable,
(Capable of performing critical ATM functions (separation, sequencing, spacing), and
(Capable of sufficient security to support authentication, authorization and encryption.

In addition, the proposed research will have certain technical design features to advance the concept:

(IPv6 based Internet protocol for messaging,
(Prioritized mixing of information packets over a single radio frequency link,
(IPsec-based security, with security associations to permanent identities as opposed to an IP address,
(Accommodation of mobile networks
(Capable of multicasting
(Scalable and extensible architecture

The parallel development of the business case addresses the value-added benefits so that at the end of the research, there is a viable business case to proceed with commercialization.

3.0 Concept of Operations – General Aviation

General aviation (GA) presents a more significant challenge in bringing this population of users into the transformation path for the NGATS. Some elements of general aviation like the business jets and fractional ownerships have more advanced avionics, but all who operate under instrument flight rules will need to transform to provide 4-D trajectory and intent information and will also need to be a ***Node-on-the-net.*** But for general aviation, there is the added burden of emulating the 4-D trajectory and intent functions, building the flight object, and managing the information. There is much more research opportunities in the general aviation market than the air carrier market. General aviation cannot replicate the avionics of air carriers, for reasons of weight, space, and most importantly cost. There is a need for both an increase in performance and a decrease in cost that can only be realized by disruptive technologies from other industry segments and by collapsing the number of avionics boxes needed for flight.

The operational needs of general aviation are:

- 4-D trajectory capabilities,
- Ability to generate intent messages,
- New access to network-provided information so as to formulate intent and gain the benefits of common situational awareness,
- Consolidation of weight, space and panel congestion over existing avionics,
- Software programmable functions to match the flight profile, providing redundancy and backup by selecting functions needed for the phase of flight,
- Plug-and-play expansion capabilities to stimulate third party development and ease of upgrade,
- Safety, comfort, and convenience improvements through integration and shared common situational awareness,
- Improved security for access to airspace and airports, and
- ***Node-on-the-net*** for general aviation.

Getting GA to the NGATS will require research investments to 1) emulate requirements and capabilities that air carrier aircraft have, and 2) driving down the cost to the users for those capabilities. There must be disruptive technology to drive up performance and drive down cost (as much as by a factor of 3). The business case can only be made if there is a savings over the combined replacement cost of existing avionics for the retrofit market and no more costly than current new installations.

4.0 Concept of Operation - Scenarios

An air carrier aircraft operates as a ***Node-on-the-net*** with the ability to attach to that network or any subsequent network through a secure handshake that authenticates and authorizes access. An information management unit (IMU) connected to the aircraft's own network extracts and maintains the flight object. The IMU can format and pack the information to meet the communications priorities, link(s) performance, and trigger the sending of messages. On the reception of a message, the IMU routes the information to the appropriate address on the aircraft's network for action by the different functions.

This scenario is focused on the realization that the avionics market for air carrier aircraft is quite mature and has been functionally integrated through a shift from stove-piped avionics to avionics on an aircraft network backbone structure. What MMDA adds is the networking gateway activities, connection, and routing of information packets and the necessary ground infrastructure to manage the connectivity.

A general aviation aircraft uses augmented GPS with suitable backup for navigation. The MMDA provides the ability to create flight object files and a method to provide intent, based on pilot defined parameters. The MMDA operates to emulate 4-D trajectory with intent through use of an airborne self-tracker and provides some additional avionics consolidations to reach an acceptable price point. For example, if the aircraft can send its flight object with each air-ground transaction, then the emergency locator is redundant and unnecessary. There is an opportunity to remove the locator beacon along with the NDB, VOR and other navigational stove-piped transceivers to reduce weight and space and realize replacement savings. There may even be a new transponder in the MMDA suite that is capable of not only interrogation response, but may also providing dependent surveillance and basic security features for airspace access. Once the aircraft can participate in 4-D trajectory-based separation, adding the ***Node-on-the-net*** capabilities supported through a similar IMU becomes a technology transfer activity from the air carrier version of MMDA.

5.0 MMDA Vision

The emphasis for MMDA is on integrated communications (C), navigation (N) and surveillance (S) functions contained within a common platform and operating system. MMDA research and development will advance the art of safety computing, reducing the time and cost of certification of the next generation of aircraft avionics.

Multi-mode means that within the functions of C, N, or S the avionics can change mode of operation through applications software. A communications function can be selected without the need to add more radios. Rather, the mode can be changed to produce different waveforms and modulation schemes. At one instant the Very High Frequency (VHF) radio could be working as a Mode 2 data link, then shift to a Mode 3 digital voice transceiver. The next instant it may be an IPv6 protocol for broadband communications. The Global Positioning Satellite (GPS) receiver can be either augmented by satellite corrections, or ground-based corrections. The transponder functions can be the existing Mode A and Mode C, Mode S, or shift to Automated Dependent Surveillance-broadcast (ADS-B).

Multi-mode allows the pilot to select the right mix of avionics for the operating environment. Instead of carrying different types of avionics boxes to accomplish different functions, the pilot can select, through software, a configuration with the needed mode of operations for the flight profile at that moment in flight. The amount of redundancy and the benefits of dispatch reliability can be programmed.

Multi-function[3] means that a single physical element of MMDA (e.g., a card in a slot) is programmable to deliver different functions. A card that is currently being used for a function like an instrument landing system (ILS) can be reprogrammed in flight to provide augmented GPS navigation. A communications device can be programmed to a different frequency with different bandwidth, delivering data link and digital voice across multiple spectrum windows. Through an emergency broadcast capability activated by the pilot or from collision sensors on the aircraft an application like ADS-B can be activated to provide the last known aircraft position.

Multi-function capabilities from the same physical device means that the pilot can use a suite of functionalities and tailor the C, N and S needs for any given flight profile. An ILS used only in landing can now be reconfigured to provide a more relevant capability. When not needed for data link, a radio can be reprogrammed to provide a different function. Avionics no longer need to sit idle during certain phases of flight, but can be reprogrammed to support a different function that aids the pilot. Multi-function packaging of avionics is not new, what is new and the focus of NASA research is the approach that allows the pilot to reprogram the functions, using less total number of physical devices and more flexibility to tailor the pilot's needs to the suite of applications.

5.1 MMDA Differs from Software Defined Radios

Software Defined Radios (SDR) are being developed and manufactured for the military. SDR is a new technology that represents the state-of-the-art in communications that produces improvements in interoperability, connectivity, security, and bandwidth utilization. It is the essential technology to connect the war-fighter with the networks necessary for network-enabled warfare. SDR is too expensive for routine use in aviation and is still confined to the limits of the communications functions. What SDR does is remove waveforms, modes, and bandwidth limitations from the equation of war fighting. SDR's are focused on moving information to and from war-fighters. Consider an SDR as a narrowly defined ***Node-on-the-net***, a portal to the possible leveraged from combat operations and network-centric warfighting. MMDA goes the next step, leveraging experience in SDR to provide the multi-function capabilities necessary for integrated C, N and S and manage the information for transfer between the aircraft and the ground and between aircraft through mobile networks.

SDR and MMDA are based on network computing concepts that start with open operating systems. SDR and MMDA focus on the movement of information. In the case of MMDA, the information may be used across C, N and S functions. The software

[3] An avionics function is a capability of the aircraft that is provided by the hardware and software of the system(s) on the aircraft that are implemented in whole or in part by electronic equipment subject to airworthiness approvals. An application is software or application-specific hardware with a defined set of logical interfaces that, when integrated with a platform, performs a function. (From RTCA SC 200)

operating system manages network functions, allows application software to be executed, and provides the fail-safe functions necessary to realize high levels of accuracy, integrity, availability, and an appropriate level of redundancy to realize the needed capabilities.

Where the SDR and MMDA differ is in the MMDA's need to meet FAA certification requirements at the information level, the operating system, and the various applications that would be supported by the MMDA. The research on MMDA is designed to create opportunities to improve and reduce the cost of certification, not only for the original equipment manufacturer (OEM), but also to other companies who want to add functionality to the basic certified MMDA configuration. The MMDA will integrate C, N and S and use software engineering to define how information will be exchanged between functions.

Another difference is the approach to the operating system. The use of open standards will facilitate how information is partitioned within the MMDA. Integrity standards will exist so that information from one application can be used by another application, with the assurance of accuracy and timeliness. It is this focus on software partitioning and the quality control over safety-critical information that is the research challenge for MMDA.

5.2 Advancing the State-of-the-Art in Certification

NASA proposes to use the principles of Design for Six Sigma (DFSS)[4] to define requirements, develop prototypes, and produce data in support of certification. The principles of DFSS reduce the uncertainty of qualitative determinations of safety performance and supports decisions based on data. The existing FAA certification policies and procedures are being mapped and NASA is working with the FAA to define areas where improvements can be made that support the concepts of MMDA.

The MMDA creates a unique opportunity to take certification to a new level with a new cost-saving approach. The MMDA creates an opportunity where use of open standards operating systems can shift certification processes. Currently, every avionics function is treated as a separate box, with different certification criteria and standards. If a new function is added, certification starts from the beginning. There is no credit given for prior performance of an earlier version of the avionics. The cost of full certification is passed on to the consumer. In MMDA, the base suite of functions, the operating system and the network are certified. Since the operating system manages the information, a new function that is added need not start from scratch and recertify the MMDA. Rather, the proposed new function is tested for compliance with information requirements of the MMDA, power budget, and related standard interfaces. Developers can test their new functions and leverage the power of the MMDA to enhance performance of these new functions.

[4] See Brue and Launsby, *Design for Six Sigma*, McGraw-Hill, 2003

If the consumer buys a certified MMDA and subsequently wants to add a new functionality, this new functionality is truly “plug and play” meaning that the physical device and applications software can be loaded into the MMDA and be expected to play as certified. The supplier of the new functionality does not need to recertify the entire MMDA. “Plug and play” means that the functionality will not interfere with other functions, impact the performance of the operating system, require changes in the operating system, or consume more power than allotted. “Plug and play” will not “play” if it is not properly configured and certified. The consumer will know that if the new functionality does not operate, the MMDA will tell the consumer. This will eliminate bogus parts and poor, unverified software.

The MMDA will also have a developer’s tool kit. This tool kit provides interface information, open source code, a network simulator for managing information throughput, and an ability to assess resource requirements from the MMDA that are needed to deliver the new function(s). The tool kit generates reports on performance of the new function(s) relative to the MMDA’s certified performance. This tool kit expedites certification by generating the data necessary to demonstrate certification of the new function(s).

5.3 The MMDA Functions Like a Computer

The personal computer is designed around an operating system that allows for concurrent applications to be run. Linux is an open operating system that allows many developers to provide high-performance computing with high reliability. A consumer can add a new function (e.g., word processing) by just adding the software application. The application knows how the operating system handles information. If a broadband communications system is to be added, a physical device and software are needed. The software is loaded and knows how to operate relative to the operating system. The interfaces are defined in the computer to allow the operating system to accept the physical device that enables broadband. If the operating system does not recognize the hardware and software, broadband communications will not work. In essence, the computer self-polices what will or will not run on it.

MMDA brings avionics into the world of open systems and network computing, providing increased flexibility and functionality without the need to constantly recertify the complete computer when you only want to add broadband communications.

5.4 Architecture Approach to MMDA

The architecture will be defined by the research; however, the basic elements are:

- An open standards operating system capable of partitioning functions,

- Information management functions that assure integrity of information used by one, some or all functions,
- Interface management functions that link MMDA to antennae and similar sensors,
- A redundant power module,
- Interface management for displays and pilot controls for the various functions,
- An on-board database,
- Virtual and physical software-programmable functions integrating C, N and S,
- An upgrade interface for loading upgrades or loading new functions,
- Software backup capabilities to protect configurations,
- Hardware and software configuration management capabilities,
- “Plug and play” access for the consumer,
- Information and physical security protection,
- Built-in test for operational use and maintenance diagnostics,
- Modular construction with sufficient capacity to support consumer expansion of functions, and
- Space and weight that is less than the combined functions MMDA is designed to replace.

The key principles of the MMDA design are:

- Reduced cost to the consumer over the aggregate replacement cost of avionics replaced by MMDA,
- Reduced certification processes and costs with credits for previous certification of MMDA for any functions that are subsequently upgraded or added,
- Drive down the development and certification time for integrated avionics,
- Increased quantitative data derived from MMDA for use in certification approvals to reduce both cost and time of certification,
- Documented information accuracy and integrity assurance[5] suitable to the function(s) required,
- MMDA support of functions and modes that anticipate future avionics needs (2010-2025),
- Sufficient physical, virtual, and power capacity to allow MMDA growth in functions,
- Traceability of information accuracy and integrity through the operating system, networking, and applications software for the functions to aid in certification and subsequent operational use,

[5] An example is position (latitude, longitude, and elevation) that may be derived from a GPS function, but subsequently used for terrain avoidance functions and for position reporting. The accuracy and integrity of the position information must meet the standards for the function that subsequently uses the information as well as the GPS function of telling the pilot where the aircraft is in the airspace.

- Availability of 0.999999 for the MMDA and 0.99999 for any single avionics function[6], and
- Integrity and accuracy requirements to meet or exceed current requirements for known C, N and S functions planned MMDA.

There is a significant need for cost reduction to the consumer. Depending on the aircraft type, avionics represents from 20 to 35 percent of the aircraft flyaway cost. For military aircraft with weapons systems this cost approaches 40 percent. A significant reduction in cost for avionics in high-end general aviation aircraft (e.g., business jets) would stimulate investments in more capabilities. A significant reduction in low-end general aviation would allow broader equipage with new technology that will be needed in the transformed National Airspace System. A change in certification processes focused on information safety and quality assurance will provide significant savings for air carrier avionics development and certification.

NASA intends to competitively award one or more contracts to first define the architecture for MMDA and subsequently to develop a prototype(s).

5.5 Certification at the Information Level

Currently, avionics are certified based on a single mode of operation or single function. There are examples of multi-mode (e.g., multimode radios) but each mode is examined separately and safety analysis shows that one mode cannot interfere with the operation of another. The avionics are not capable of simultaneous use of different modes; rather the pilot must select the mode. Multiple functions may exist in a common box, but each is addressed separately for certification and shared common elements (e.g., power supply) must show that both functions can be supported.

With MMDA, the focus changes to information certification. If you want to define functions with software, the software must be certified to certain safety levels depending on the function, and the information accuracy and integrity must be certified so that the information created by one function can subsequently be used by another function. This may be the raw data from one function to another, or processed data by one function before handoff to another. This focus on the information includes its security as well, from database content to transient information that is derived by one and shared by other functions. Where and how information from one function is transported to another function must be defined and demonstrated for certification. By certifying at the information level, the certification burden is reduced for companies building new or enhanced functions. Companies would need to demonstrate that their information can be integrated into the existing MMDA information flows and the MMDA, in combination

[6] Availability should be set by the flight critical functions and lower availability can be attained for advisory, comfort or convenience functions (e.g. Internet access). Availability can be attained by dual virtual equipage (e.g. being able to program one function to be a backup to another like function).

with their own applications software, can deliver the proper data quality, accuracy and integrity.

The NASA investment in developing MMDA and a roadmap for certification at the information level reduces the risk for manufacturers and brings manufacturers toward open standards and operating systems as opposed to the current proprietary systems that are driving excessive costs to the consumer. NASA's leadership and partnership with the FAA can lead to different certification processes that actually implement the recommendations from RTCA Special Committee 200 on Integrated Modular Avionics.

6.0 Markets for MMDA

Why must there be a federal research investment? The role of NASA is to pioneer and validate high-payoff aeronautical technologies. Once the technologies are defined, NASA will extend the benefits of innovation throughout the aerospace industry and aviation's customer base. There is a piece of MMDA innovation for each customer.

The success of NASA research is measured by the extent to which others use research results. MMDA is the next generation of avionics, delivering both integration of functions and a new focus on avionics that parallels global changes in air traffic management with an emphasis on network-enabled operations. The MMDA is the node on this global network.

Benefits and equipage are dependent on the timing of technology transfer from NASA to the aeronautics industry and subsequent use of the product. For the following list of benefits, the assumption is that research and development are completed by 2009 and certified MMDA systems become available by 2012. On the air carrier side, Airbus and Boeing will have already introduced the A-380 and B-7E7 to commercial service and Airbus will have just started to deliver a modification to the 150-200 seat class aircraft. MMDA research will not influence these systems because commitments have already been made for the avionics. However, Boeing will likely have another derivative of the versatile B-737 and will have expanded its business jet option (BBJ). Airbus will continually reinvent the smaller A-319 to "right size" the aircraft for the short haul market. All three of these aircraft represent possible MMDA markets. It is unlikely that MMDA will represent a retrofit opportunity for classic aircraft for air carriers.

Regional jets will continue to expand, especially in Asia and Europe. These aircraft are opportunities for both new equipage and retrofit. The trend today is for larger 55-75 seat versions. The regional jet market is expanding rapidly. In the United States by the end of 2004, approximately 560 RJ aircraft are operating. This will grow to between 3,300 and 5,000 by 2022.

There are approximately 8,000 business jets flying, with an expected growth to 12,300 turbojet/fan aircraft by 2014. This number could be as high as 16,000, being driven by fractional ownership arrangements. The business jet consumers are more likely to embrace the latest available technology and MMDA could drive about 4,000 units of existing aircraft types. However, there is considerable interest in a new generation of supersonic business jets. This aircraft would emerge about the same time that MMDA becomes available. Both the General Aviation Manufacturers Association and the National Business Aircraft Association are defining the potential market for supersonic business jets now. Business aviation is in the business of delivering timesavings and predictability for passenger service. Predictable access to airspace and airports is a driving business imperative.

An exciting segment of the future market is the micro-jet. This new growth segment, the 4 to 6 passenger jet aircraft currently entering flight test and certification. Eclipse is the furthest along, but the number of micro-jet manufacturers is growing. Eclipse has 2,100 firm orders, plans to ship 1,500 aircraft per year, and will complete performance flight tests in August 2005.[7] Current demand is close to 8,000 aircraft and could go as high as 15,000 aircraft by 2025.

James Coyne, President of the National Air Transportation Association has coined the phrase the *Third Dimension in American Air Transportation*. The micro-jets bring speed, safety, security, flexibility and independence of the private aircraft and open up affordable, fast travel. He emphasizes that since the start of the jet age, air transportation has been two dimensional – large, fast aircraft with professional pilots, and small, slow, private planes flown by private pilots. The traveler’s choice is large and fast, or small and slow (except for those able to afford a business jet). The micro-jet shatters this paradigm and creates a new competitor for airspace, right up there with the “heavy metal.”

The least expensive business jet has a production cost of about $4 million and an operating cost of $1.62/mile. The micro-jet will be smaller (by 15-35%) and slower (5-10%) but cost close to $1 million with a forecasted operating cost of $0.69/mile. This new industry is very cost and price point sensitive and would readily embrace an integrated avionics capability that has expansion capabilities and would allow their customer to invest in the avionics functions they need for their mission profiles.

The micro-jet also presents a different business model for fractional ownership and air limousine services. This reduced cost of ownership opens up the opportunity for fractional shares to grow over 4 times the current population of fractional owners. Fractional ownership could approach 350,000 to 500,000 members by 2020.

[7] See Eclipse Aviation web site for schedules at www.eclipseaviation.com/

Another phenomenon is happening with the smaller general aviation aircraft market. Cirrus[8] is selling integrated systems and aircraft that are easy and economical to fly. The small aircraft industry is transforming and becoming price-point competitive and savings in highly integrated avionics can directly translate into more sales. Cirrus has taken advantage of some of the NASA Small Aircraft Transportation System research and composite materials work to produce a new generation of light aircraft. The small aircraft market is growing and increasingly being focused on instrument operations due to Cirrus and other's work on integrating the presentation of information from the avionics. Weight and space considerations are important to this segment.

On the retrofit side, the market is only as strong as changes in the NAS. If the FAA begins to restrict access because of lack of equipage, or equipage produces real benefit in terms of saving time, improving comfort and convenience, or increasing access, then the existing fleet of small aircraft will retrofit. The community of aircraft operators and owners are faced with serious space problems for more avionics and display real estate on the dashboard. The sellers of avionics are bundling the pilot interface and filling the plane with electronics. In a retrofit, the price point will be important and should be less cost than the aggregate existing avionics cost with weight and space recovery realized.

The next market segment is the unmanned aerial vehicle (UAV). These vehicles currently operate in the NAS based on exception, not as an integrated flight operation with manned aircraft. If UAVs are going to be integrated, they will need similar functions as manned aircraft and MMDA offers the opportunity for an integrated C, N and S capability by consolidating stand-alone functions for lower weight and space considerations. UAVs that will operate into existing airports will need instrument capabilities for guidance. UAVs operating at low altitude will need precision positioning for terrain avoidance and be able to operate for flight segments as autonomous aircraft. UAVs will need both terrain and aircraft avoidance capabilities. The MMDA offers the users of UAVs an opportunity to tailor their needs for specific mission profiles through software programmable functions.

7.0 Benefits of MMDA

The benefits accrue to different users and service providers of the air transportation system depending on their types of aircraft and operations. The following is a qualitative list of categorized benefits that will be expanded as part of business case development over the research period. It will be important for NASA Glenn to have the developers capture qualitative and quantitative estimates of benefits.

8.1 Global ATM

[8] See Cirrus Aviation web site for aircraft descriptions at http://www.cirrusdesign.com

- Interoperability
- Increased options for communications
  - Voice
  - Data
  - Broadband
- Improved surveillance
- Precision positioning
- Aircraft intent

7.2 NAS

- Global ATM benefits
- Access
- Autonomous aircraft operations
  - Aircraft and UAVs in low-density airspace
  - Sense and avoid concepts
- Network enabled operations (“***Node-on-the-net***”)
- 4-D trajectory-based separation, sequencing and spacing

7.3 FAA Safety Organizations

- Network enabled information access
- Quantifiable evidence for accuracy, integrity and availability for airworthiness approvals (certification)
- Certification at the information level
- Lower cost to certify from FAA workload perspective
- Technical standard orders tailored to functions within the base MMDA architecture

7.4 Avionics Manufacturers

- Lower risk to certify because of NASA research investments
- Simplified certification process
- Increased competition with lower consumer cost
- Open systems standards
- Lower cost of certification
- “Credit” for previously certified elements of MMDA

7.5 Aircraft Manufacturers

- Lower weight and space requirements
- Less cockpit dashboard real estate consumed by controls for functions
- Improved airworthiness processes

- Retrofit options that can be packaged to customer's needs

7.6 Air Carriers (including regional carriers)

- Reduced weight and space
- Upwardly compatible to add functions based on needs
- Lower unit cost and flyaway aircraft cost
- Improvements in minimum equipment list for dispatch reliability
- Lower diversity of avionics needs to be maintained
- Programmable upgrades as opposed to removing the aircraft from revenue service for avionics changes
- Increased capabilities for access in congested airspace
- Management of information flows with network-enabled operations
- Global compatibility and interoperability
- Greater access to information for airborne flight planning

7.7 Business Aviation

- Global compatibility and interoperability
- Minimum equipment list for dispatch is programmable
- Space and weight savings
- Management of information in a network-enabled air transportation system
- Predictable performance
- Broadband capabilities
- Ability to select communications options based on mission profile and service provider costs (choices for data link and broadband)
- Tailored avionics to the mission flight profile
- Greater access to information for airborne flight planning
- Increased capabilities for access in congested airspace
- Upwardly compatible to add functions based on needs
- Lower unit cost and flyaway aircraft cost
- Lower diversity of avionics needs to be maintained
- Programmable upgrades as opposed to removing the aircraft from revenue service for avionics changes

General Aviation

- Global compatibility and interoperability
- Space and weight savings
- Recovery of dashboard real estate for improved avionics
- Management of information in a network-enabled air transportation system
- Predictable performance
- Broadband capabilities

- Ability to select communications options based on mission profile and service provider costs (choices for data link and broadband)
- Tailored avionics to the mission flight profile
- Greater access to information for airborne flight planning
- Increased capabilities for access in congested airspace
- Upwardly compatible to add functions based on needs
- Lower unit cost and flyaway aircraft cost
- Lower diversity of avionics needs to be maintained
- Programmable upgrades as opposed to removing the aircraft from service for avionics changes
- Common human interfaces between aircraft makes and models (aircraft rentals)
- Ability to add safety advisory capabilities (e.g., terrain alerts) at lower cost
- Improved training (e.g., a systems approach to integrated C, N and S)

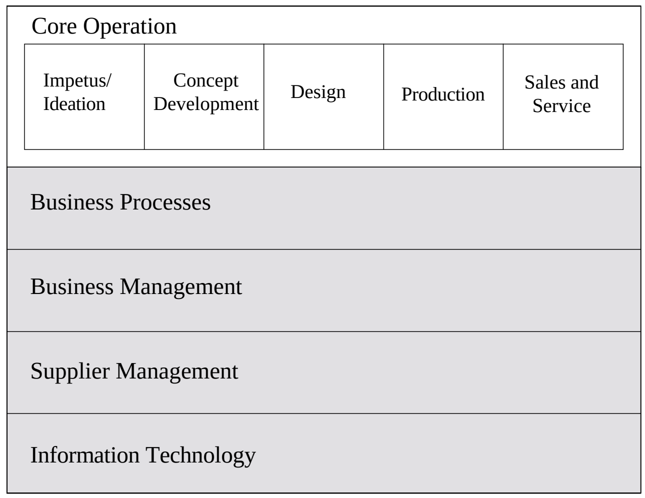
7.9 UAV Operators

- Global compatibility and interoperability
- Space and weight savings
- Management of information in a network enabled air transportation system
- Predictable performance
- Ability to select communications options based on mission profile and service provider costs (choices for data link and broadband)
- Tailored avionics to the mission flight profile
- Increased capabilities for access and integration into the NAS
- Upwardly compatible to add functions based on needs
- Lower unit cost and flyaway aircraft cost
- Lower diversity of avionics needs to be maintained
- Programmable upgrades as opposed to removing the aircraft from service for avionics changes

As interviews with users are conducted, additional benefit opportunities will be discovered. The objective of MMDA is to match user needs with the technology to make the business case for successful technology transfer from NASA to the aerospace industry.

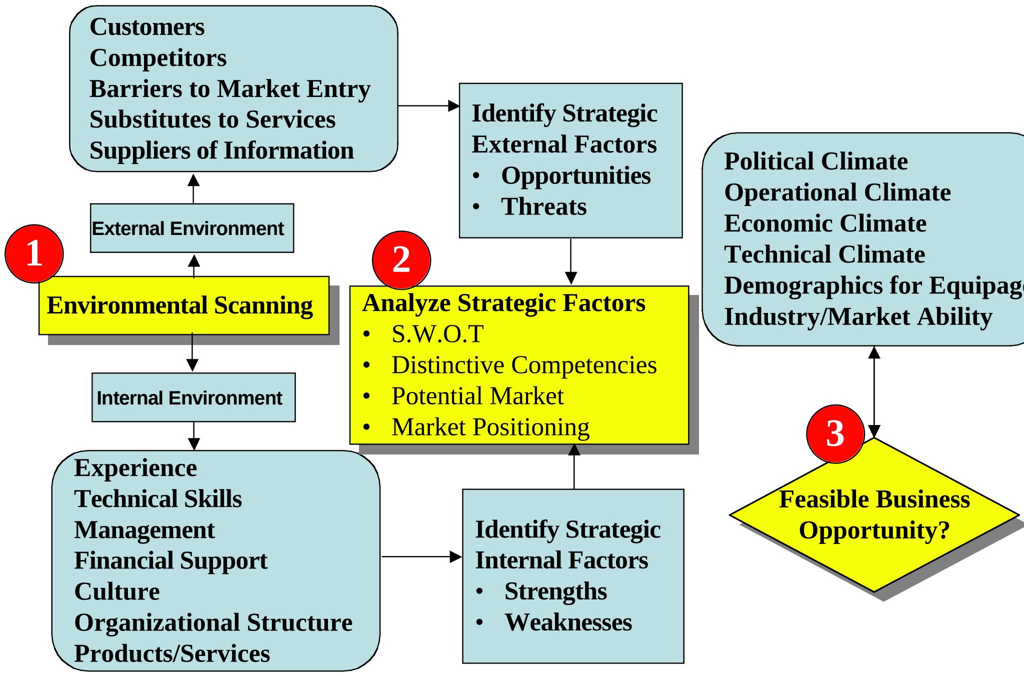
8.0 The Business Case Model

A business case is an analysis of the potential market, the capabilities of the company, and the alignment of customer needs with company capabilities to produce the product. The business case is easy if there is a readily identifiable customer who knows what she or he wants, and your company can see profit in producing the product. However, in most cases in aviation, the market must be created by significant up-front development costs, certification costs, and after-market support. The company must decide whether there is sufficient market to take on the risk of this up-front investment. ***Getting to yes*** to commit resources for commercialization must be data driven and is characterized in some companies as a gate review – management check points along the way that validate business assumptions, technical feasibility, and place in the market (competitive position, price point, service, etc.).



For MMDA, there are opportunities to use NASA research to significantly lower risk to the manufacturer in terms of both cost and technology. Manufacturing companies typically have a business operation model[9] that involves core operations and business support activities. What the business case does is examine the cost, return on investment, risk, and quality requirements around each of the five core operations in manufacturing. Under the proposed research for MMDA, the ideation, development and design will be supported for at least one manufacturer to provide high-risk, high-reward creation of a new concept in avionics. The results will be shared with other manufacturers through technology transfer activities to stimulate the market and reduce costs to the users of the avionics.

[9] From Yang and El-Haik, Design for Six Sigma, a Roadmap for Product Development, McGraw Hill, 2003



This business case model is an approach to gathering information to determine whether there is a viable market for MMDA. The model will be used for the commercialization of MMDA.

The first step is environmental scanning, both internally and externally. Since the ACAST effort is new, the internal scanning would start with the project office. As the research progresses and companies are selected, part of that selection is based on their own internal environment. Do the companies have the right experience and technical skills? If NASA Glenn is seeking disruptive technology, does the company have a history of adapting technology from one market into another?

The second step is an analysis of the strategic factors, the strengths and weaknesses from the internal environment and the opportunities and market threats from the external environment. Distinctive competencies are those discriminating factors that advantage the company in the market place. In the case of research, this competency can be measured under Design for Six Sigma as time to market – from ideation to sales.

The third step is to assess the political, operational, economic and technical climate for the product. This is especially important with MMDA, because the Federal Aviation

Administration is the driver of the market in terms of timing, services to be provided, and willingness to accept the results of the research, development and design.

Once the strengths, weaknesses, opportunities, and threats are identified, a SWOT matrix can be formed as a way of leveraging strengths and opportunities and managing weaknesses and threats.

SWOT	Opportunities	Threats
Strengths	• Internal and External alignment is strong • Opportunities with little resistance • Close alignment between work and customer needs	• Risks (political, operational, economic, technical) against organizational strengths • Mitigation increasingly dependent on agreements between parties
Weaknesses	• Internal weaknesses dilute the opportunities • Manifested in lack of leadership in advocating the opportunities • Not well positioned to deliver the opportunities	• Areas where there is an external threat against an internal weakness • Projects are difficult to support because of external influences • Internal weaknesses magnify the external threats

By making weaknesses into strengths and changing threats into opportunities, there is a much stronger business position in the market place. Threats that exist against weaknesses usually fall away as the weaknesses become strengths. A simple example is taking the leadership to advocate the opportunities. It shows that NASA Glenn is doing the right research, at the right time to stimulate the transition to the NGATS. External alignment toward the research effort breaks down the threats.

Using the concept of operations as the basis for the model, three SWOT matrices were defined. The first is for NASA Glenn and the project office since no development contracts have been awarded. When soliciting for a developer(s), the business case model can serve as input to section L and M of the solicitation to identify the right skill set and capabilities. For example, if disruptive technology is needed from the telecommunications industry, does the perspective vendor have strength in taking communications products from idea to market (time to market for representative products).

8.1 NASA Glenn SWOT

The NASA Glenn SWOT reflects where the ACAST Project is in the process of defining the vision and concepts of MMDA. Early in the development, it affords an opportunity to

NASA Glenn SWOT

S W O T	Opportunities	Threats
Strengths	• High-risk, high-reward investment to change the current concepts of avionics • Strong communications credibility • N and S have greater communications needs than previous avionics • Leading certification at the information level so as to gain integrated certification credit for MMDA concept	• Demonstration of new functionalities by service providers like ARINC or SITA that accomplishes same objectives • Internet for the air - rogue or integrated stepping stone • Security efforts at Glenn but outside of ACAST program to establish connectivity with the aircraft and air marshals • Programmatic linkage to JPDO Agile ATC IPT
Weaknesses	• Isolated from the customer (NAS users) • Focused on the avionics manufacturer where the objective is to leverage the telecommunications industry and open standards • Alignment of Glenn resources with the technology as opposed to the applications (functions)	• Understanding the market - Voice of the customer • Lack of funding to support multiple MMDA developers • Distraction of NASA/FAA work with Europe on a next generation communications structure • Lack of crisp description of multi-mode and multi-function • Risk from RTCA SC 200 approach being new and unproven/accepted by FAA • Open standards versus proprietary culture of avionics manufacturers

structure the leadership challenges to turn threats into opportunities and convert weaknesses into strengths. The principal competition for this research is from the commercial aeronautical service providers who have invested in the ground network to support VHF data link. The balance of the threats can be neutralized and turned into strengths by building relationships with the Agile ATC IPT of the JPDO and internal coordination on security work that may be supported by the ACAST capabilities.

8.2 Air Carrier SWOT

The air carrier SWOT is primarily driven by immediate economic concerns over airline profitability. This is causing a very near-term focus on changes. The airlines will not invest in new technology without clear, guaranteed benefits (meaning that if equipped the FAA will deliver the service). A significant current economic factor is the price of fuel. The International Air Transport Association is reporting that the airlines can be profitable with oil prices at $35 to $37 a barrel. Some U.S. airlines are saying $34 per barrel. The current price is $51 per barrel. Fuel savings and efficiencies will be a significant business driver for the airlines.

Another threat area is the International Telecommunications Union classification of safety services for spectrum allocation. As we move toward network-enabled operations, the line between pure use of spectrum for surveillance and navigation gets mixed with the less restrictive communications spectrum.

Air Carrier SWOT

SWOT	Opportunities	Threats
Strengths	• 4-D trajectories understood as necessary transformation • Network-enabled operations understood as necessary for transformation • New communications structure needed to realize the operations concept - node-on-the-net easily understood • Global interoperability • Focus on information elements traveling to and from aircraft • Fuel cost increases	• Lack of airline funding and short-term investment focus • Commercial service providers' concerns over open systems • Security bits overhead relative to available bandwidth • ITU characterization of surveillance/navigation versus the more liberal communications characterization of safety services • "Internet" perception of safety, security, and performance
Weaknesses	• Perception that funding will be new investment as opposed to replacing something the airlines currently carry • Lack of clear benefits without packaging multiple functions that produce short-term benefits • Looking for the 100% solution	• "need" to integrate voice and data where voice communications will continue for an extended period of time • Focus on the link - not the content • Commercial Internet access from the air as a commercial venture - competing with Government research

Every pilot knows the performance of the Internet and the perception is that its performance is not adequate for aviation. There is a significant difference between the Internet and IP-based network performance dedicated to aviation. It will be important for the ACAST project to promote the differences between the Internet and the ***Node-on-the-net***.

Emphasis on value-added benefits should be directed toward changing operational performance, specifically increasing efficiency of operations.

There is a threat from the 100% solution, integrating voice and data. While integration is desirable, the reality is that voice communications will be around for a very long time. Adding digital voice increases complexity, causes the loss of the party line, and does little to reduce cost or improve performance.

8.3 General Aviation SWOT

The general aviation SWOT Opportunities are based on wide acceptance of the glass cockpit and integration of navigation functions with moving maps and terrain data. There is continuing demand for graphical weather products and the ability to "see" other traffic by electronic means. The greatest need associated with integration is to reduce costs of avionics, for both the retrofit and new aircraft market.

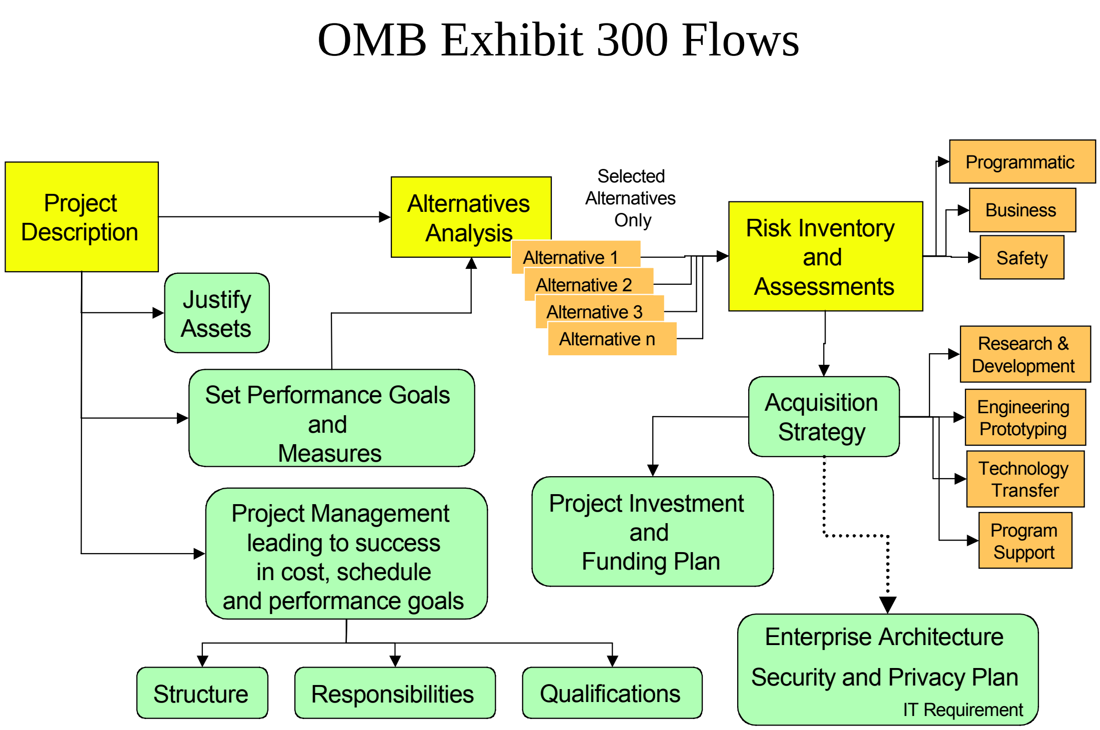
General Aviation SWOT

SWOT	Opportunities	Threats
Strengths	• Wide acceptance of "glass cockpit" with multi-function avionics • User desires for "Internet-like" capabilities for weather, NOTAMs, and NAS status Strong demand for weather and airspace access information • Need to lower cost of avionics for both new and retrofit markets • Buy-back of weight, space, and complexity of use	• Market size is small relative to other infrastructures (telecommunication, financial, medical, etc.) • Lack of endorsement of MMDA due to lack of understanding • Multi-function integration of avionics (e.g., navigation with maps and terrain) • Market division by avionics manufacturers produces vastly different functions between air carrier and general aviation aircraft - one size is not marketed to all
Weaknesses	• Lack of understanding of "what could be" • Lack of clear vision on MMDA • Elimination of existing avionics through integration can save replacement costs • Safety, comfort and convenience drive investments	• Regulatory relief may be needed to remove equipment from aircraft • High cost and proprietary development by avionics manufacturers

The threats include the continuing trend in general aviation avionics to add more functions, especially for navigation and communications. The continued transition to glass cockpit configurations is offering the avionics manufacturers opportunity for new product lines. To enter with the MMDA that uses technology from outside of aviation to increase performance at lower cost creates direct competition to the general aviation community market.

9.0 OMB Exhibit 300

The OMB Exhibit 300 is a method of describing the business case for a federal investment. These exhibits are part of the annual budget process at the budget line-item level. The OMB Exhibit 300 reflects a process flow that is illustrated below:



The process flow helps to justify the federal investment. Justifying the assets includes the following specific questions to be answered on the Exhibit 300:

How does this investment support your agency's mission and strategic goals and objectives?

Answer: The MMDA element of the ACAST Project supports the NASA mission to understand and protect the home planet. NASA's investment in aeronautics plays a key role in solving the challenge of increasing demand for air transportation in a time of limited industry segment growth and profitability. The MMDA is designed as a two path development. One path is to support air carrier operations by linking the aircraft and the ground with improved communications to enable 4-D trajectory-based separation, sequencing and spacing and to allow the aircraft to participate in network-enabled operations. Research will prototype and define the architecture and requirements for making the aircraft a node-on-the-net of the Next Generation Air Transportation System

(NGATS). The second path is to conduct high-risk research to bring general aviation aircraft access to the NGATS by emulating the capabilities of air carrier aircraft though development of MMDA and drive down the cost of avionics through the use of disruptive technologies for both the retrofit and new general aviation aircraft market. Both paths lead to network connectivity for aircraft and other improvements so that the National Airspace System can accommodate three times the demand.

How does it support the strategic goals from the President' Management Agenda?
Answer: This project is not part of the President's Management Agenda.

Are there any alternative sources in the public or private sectors that could perform this function?
Answer: No. Federal investment in this research is necessary to reduce risk for future manufacturers and lower the cost for users. The current trends in avionics development are leading to significant increases in cost to the user and making it increasingly difficult to provide federal services for air traffic control because of this divergence in avionics performance.

If so, explain why your agency did not select one of these alternatives.
Answer: Not applicable.

Who are the customers for this investment?
Answer: The customers are the users of the National Airspace System, including pilots, passengers, and cargo handlers who rely on air transportation. In addition, this research is focused on enabling technology to allow the NAS to transform to the NGATS that is highly dependent on information exchange between the aircraft and the FAA to reduce uncertainty of position and intent, to gain efficiencies that will reduce fuel consumption, and allow the FAA to meet the expected three-fold increase in demand by 2025.

Who are the stakeholders of this investment?
Answer: The stakeholders include the avionics and aircraft manufacturers, the DOD, the DHS, FAA, pilots, controllers, and flight dispatchers.

If this is a multi-agency initiative, identify the agencies and organizations affected by this initiative.
Answer: Yes. Agreements exist with the FAA on development of future communications strategies. The ACAST project is also working with the FAA on certification processes to reduce the time and cost of certification. There are security applications proposed within the MMDA whose requirements will be coordinated with the DOD and DHS.

If this is a multi-agency initiative, discuss the partnering strategies you are implementing with the participating agencies and organizations.
Answer: Formal memorandum of agreement with the FAA on mutual areas of support.

How will this investment reduce costs or improve efficiencies?
The MMDA portion of the ACAST Project will:

- Increase global interoperability
- Reduce cost of certification for both the FAA and the manufacturer
- Act as the enabling technology to gain fuel consumption efficiencies through the use of 4-D trajectories and optimum flight profiles.
- Reduce cost of avionics by using open standards and operating systems in the MMDA
- Reduce the number of avionics boxes required for flight

List all other assets that interface with this asset. Have these assets been reengineered as part of this investment?
Answer: Aviation Safety and Security Program – secure communications
Secure communications is a short-term effort expected to end in FY 2007 and is being performed by NASA Glenn.

10.0 Business Case Information Needs From MMDA Research Contract

The contract(s) for development of MMDA needs to mature the business case as research proceeds. The following are a series of "shalls" for the statement of work:

1. The contractor shall define the potential market for MMDA to include:
   - A summary of the demographics of equipage (number of aircraft by type),
   - An expected percent of fleet equipage over time, using 2012 as the base year, and
   - An expected year where benefits can begin to be realized.

2. The contractor shall identify barriers to market entry.
3. The contractor shall provide a plan with metrics that describes the time to market.
4. The contractor shall provide a plan for production that includes expected revenue, net present value, capitalization cost estimate, operating cost estimate, and return on investment.
5. The contractor shall quantify the expected benefits to be realized by transitioning to the MMDA from existing avionics.
6. The contractor shall provide the expected unit price and quantity discounts for the MMDA.
7. The contractor shall describe the political, operational, economic and technical climate for production of the MMDA and identify barriers to market entry.

8. The contractor shall develop a marketing plan that describes the contractor’s approach to marketing the MMDA to both the air carrier and general aviation market.

These requirements cause the research organization to think about the market as it develops the MMDA. At the same time, NASA Glenn can use this information to project and promote the potential market.

11.0 MMDA Summary

The MMDA represents a high-risk high-reward research challenge that can 1) revolutionize the integration of C, N and S; 2) change the way avionics are certified as airworthy; 3) provide a way to drive down costs to the consumer; 4) open up the avionics market to new products, functions and services; 5) assure global interoperability; and 6) support transformation of air traffic management through network-enabled operations. The aircraft becomes a node on the network where information flows to and from the aircraft to all others connected to the network, gaining efficiencies and productivity gains in air transportation. While challenges lie ahead, there is no doubt as to the needed direction and leadership for change in avionics.

12.0 Commercialization Report

The Commercialization Report will expand on this initial business case report by further data collection for the business case model and adding a roadmap to commercialization. A range of scenarios will be used to capture the range of potential benefits for those listed in this report. At this stage in MMDA development, scenarios will range from just a method of providing broadband connectivity to full integration and virtual functions within the MMDA. The Commercialization Report contains the following:

- Context of the Market Starting in 2012 through 2020
- Integration approach that realizes value-added benefits
- Value Proposition – why would the customer what to invest
- Market size projection
- Solution sets – what problems will MMDA solve
- Price point by class of user (Air Carrier, Regionals, Fractional Ownerships, Business, and General Aviation
- Benefits mapping to NGATS
- Recommended goals, objectives and metrics for tracking progress on the path to commercialization